Lessons Learned in the Development of Avionics for Modern Microsatellites

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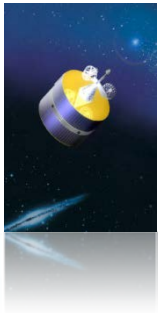
Agenda

- Introduction
- Background
- Avionics Development for microsatellites
- Lessons learned during the Development
- Conclusion

Organization

CAST
Key Member
of CASC

CALT



SAST

CASC

CASC

AASPT
AALPT
SCAIC
CAAET
…
…

CGWIC	Commercial Trading Company
ALIT	Defense Trading Company
CSCC	China's Sole Satellite Operator

CAST industrial footprint

Beijing
16036 people

Tianjin
1357 people

Yantai
1196 people

Inner Mongolia
583people

Lan Zhou 1809 people

CAST Xi'an
2672 people

Shen Zhen
133 people

15 subsidiaries in 7 cities
3 Representative Offices Abroad

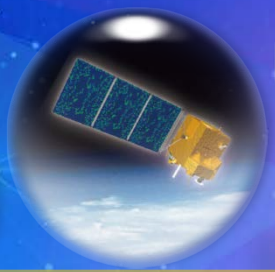
Core Business

CAST

Space

Spin-off

Telecommunications



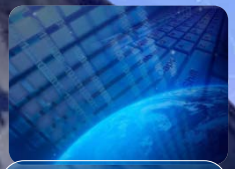
Remote Sensing

Navigation

Science Exploration

Manned Spaceflight

Satellites Application



Elelctronic Information Systems

Civilian Engineering Systems and Equipment

Space Segments

➢ **We design, build and deliver end-to-end space systems:**

◆**168 spacecrafts delivered**

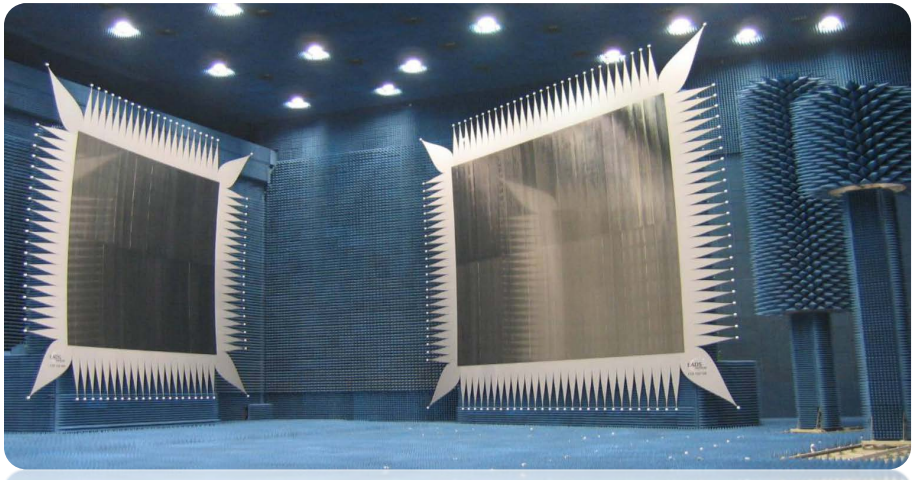
◆**88 spacecrafts in orbit**

Providing worldwide customers with full range of space to ground solutions

Telecommunications

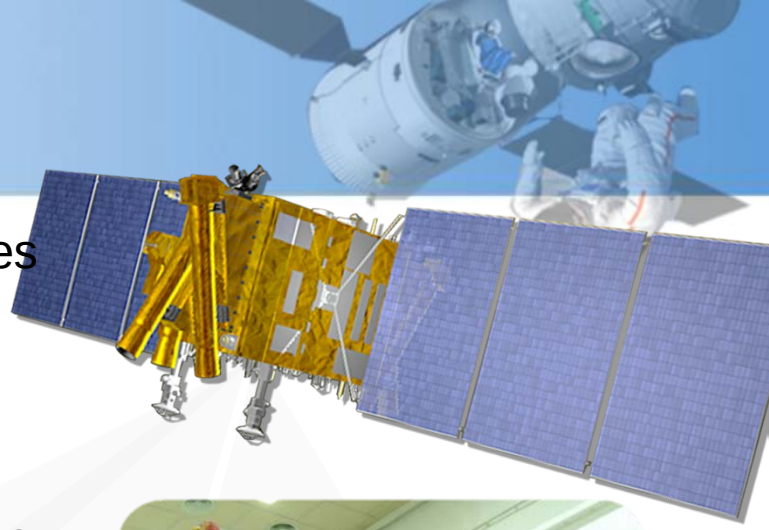
Prime contractor for over 30 telecommunications satellites

- **Turnkey Solutions**
  - **Consultation**
  - **Orbit Frequency Coordination Support**
  - **System Design & Integration**
  - **Satellite Manufacture**
  - **Launch and In-orbit Operation Support**
  - **KHTT**
- **Mature DFH platform series for telecommunication, broadcast and customized missions**
- **Reliable and customized payloads**



Remote Sensing

Core Player for over 80 Remote Sensing Satellites



Space to Ground turnkey solutions

Versatile LEO/SSO/GEO satellites and constellations

High performance and innovative bus & payloads

Reliable ground application system

Navigation

Prime constructor of China's Beidou Navigation Satellite System

- **The 1st generation: 4 satellites**
- **The 2nd generation:**

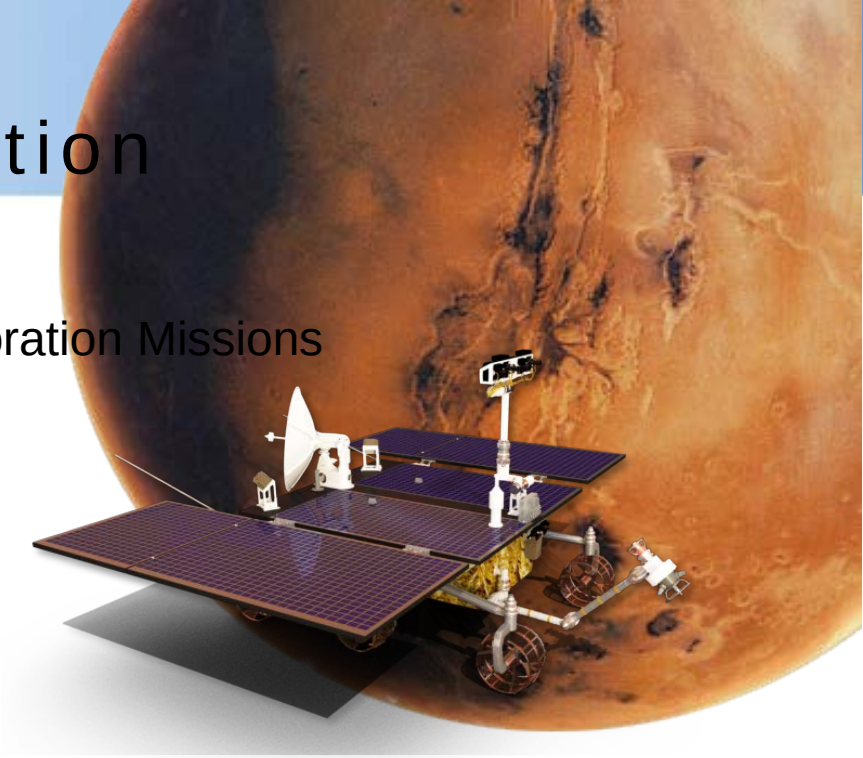
  16 satellites offers regional services for Asia-Pacific area by 2012.

  35 satellites will offer global coverage by 2020.

Beidou navigation satellite applications

- **Intelligent transportation**
- **Disaster Relief**
- **Emergency Command & Control**
- **National security**
- **Precise Timing**

Space Science Exploration



A prime role in China's Space Science Exploration Missions by delivering over 15 satellites

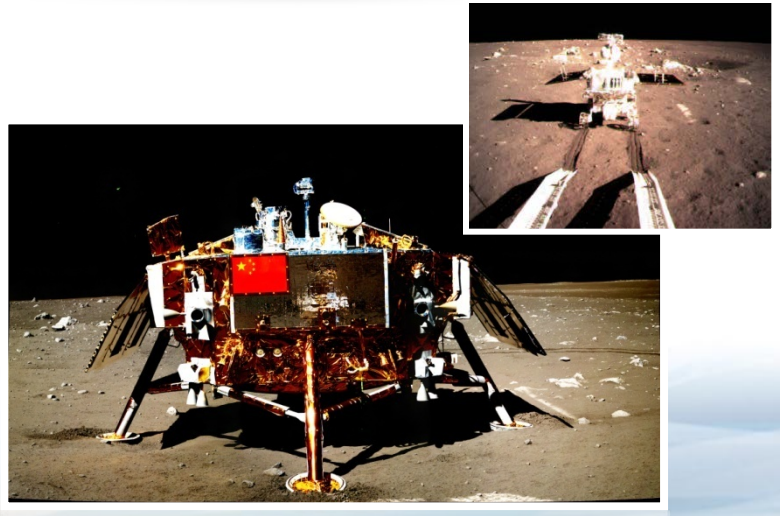
Prime contractor of China's Lunar & Mars Exploration Program

CAST carries out lunar exploration by three steps.

Orbiting
Orbiting around the moon

Landing
Soft-landing on the moon surface

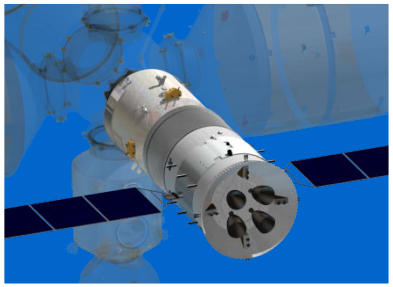
Returning
Sample collection of moon surface and returning to the Earth



Human Space Flight

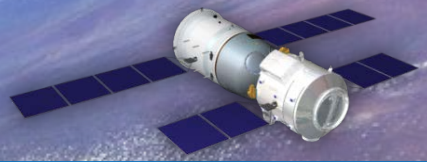
Founder of China's Manned Space Program
Successfully launched 10 Shenzhou spaceships and 1 Space Lab, will build China's first space station

China's Manned Space Program is implemented by three steps.



Manned Space Flight

STEP 1



EVA, Space lab rendezvous & docking

STEP 2

70-ton Space station

STEP 3

Spacecraft Subsystems and Equipment

Reliable supplier of spacecraft subsystems and equipment
100% subsystem and more than 90% equipments design and manufactured by CAST

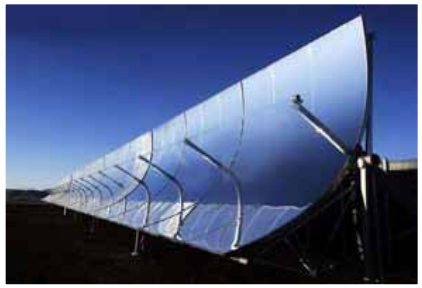
- **High performance orbit control and propulsion subsystems**
- **More than 90% self-manufactured Optical Camera**
- **All types of Antennas**
- **Reliable Self-developed Robotic Arm**

Space Technology Applications

- **Satellite Applications**
- **Electronic Information Systems and Products**
- **Civilian Engineering Systems and Equipment**

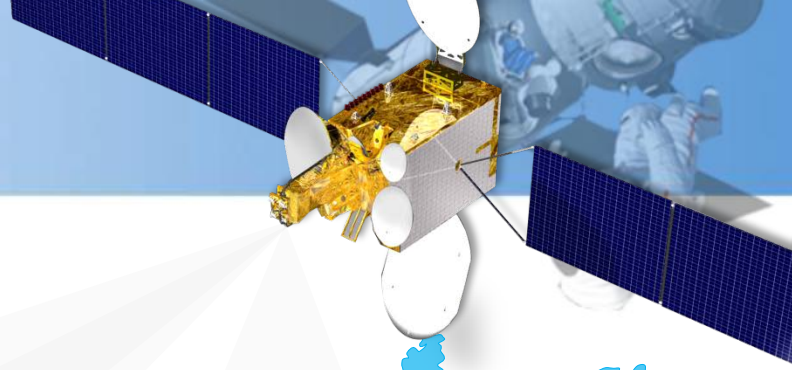
Satellite Applications

Electronic Information Systems and Products



Civilian Engineering Systems and Equipment

Global Partners of CAST



Introduction-what we do

Shandong Aerospace Electronics Technology Institute is one of 15 subsidiaries of CAST. We deals with the space data system application , integrated avionics, computer application、TM&TC、Power control and distribution are several key fileds.

Part of products:

Integrated RTU

Transceiver

TMR OBC

Power Control Unit

current limit protector

Pneumatic pressure discharge valve

Introduction-where we from

Yantai city lies in Shandong province of China, it's a seaside city. It is famous for its sea food, wine(Zhangyu) and fruits(apple, pear, cherry, etal.)

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- Avionics Development for microsatellites
- Lessons learned during the Development
- Conclusion

Background

- microsatellite widely used in communication, remote sensing, reconnaissance, mobile internet, etc.
- NASA promote quicker, better, cheaper guidelines
- formation flying or constellation
- more autonomy
- limit life, cost and functions satellites, such as cubesat, phonesat, Femto sat, etc.

these new characteristics and new application mode bring new requirements to on-board avionics of microsatellites. That is how to develop on-board avionics in a quicker, better and cheaper way?

here, I would like to share some lessons learned with the development of the integrated modular avionics for the fly formation remote sensing satellites, whose life are 6 months.

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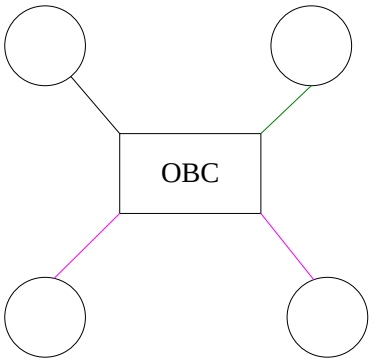
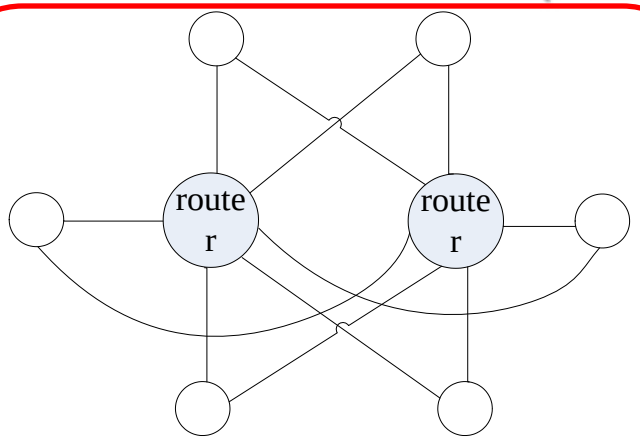
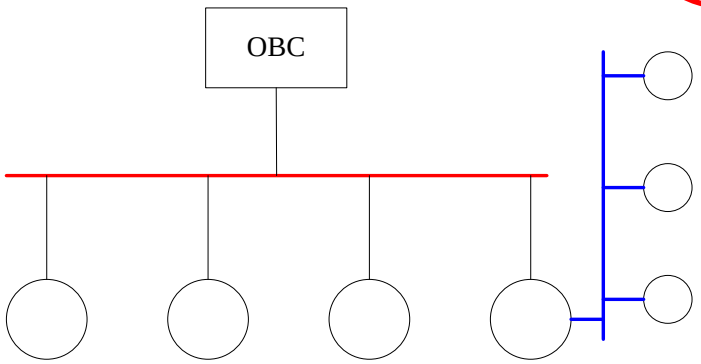
On-Board avionics system architecture



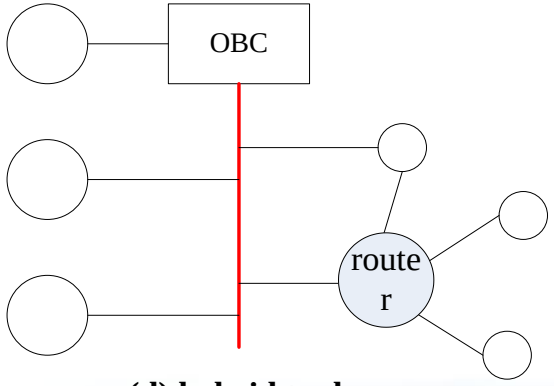
(a) star topology



(b) double star toplogy



（c）bus topology



(d) hybrid toplogy

Electronic equipment

OBC On-board computer

bus

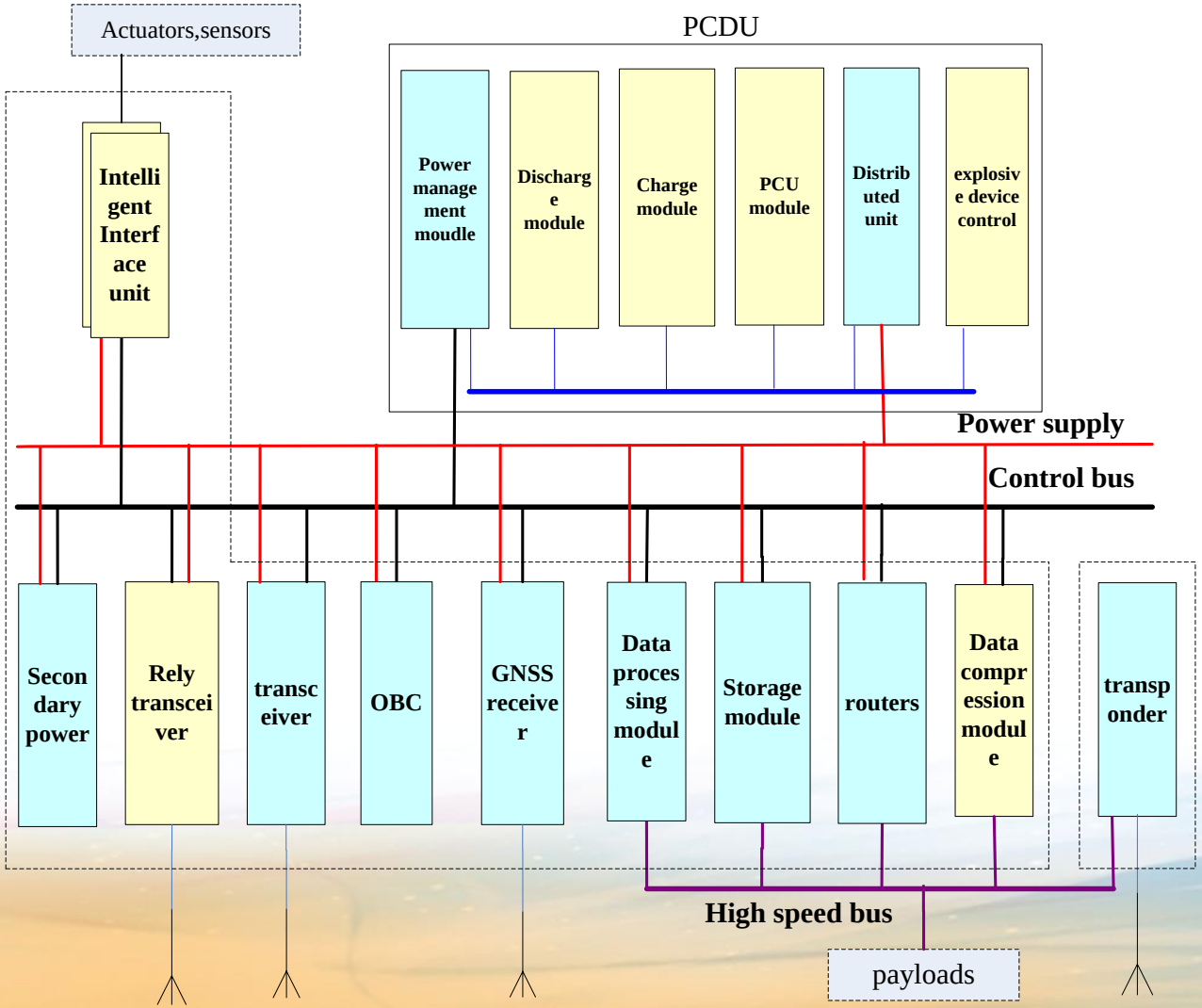
Secondary bus

Point-to-point line

Router node

On-Board avionics system architecture

The architecture of the on-board electronic system for remote sensing micro-satellites is a hybrid topology.



Standardization

Modularization

Combination

Simplify the connection between modules, and use standardized interfaces

On-Board avionics system architecture

In order to reduce avionics cost, these flying formation satellites adopt a common products off-the-shelf, which can reduce the development cost through the mode of batch development and test.

However, requirements of the avionics among different satellites are also different, the hybrid topology is an open system architecture, which supports system function module to increase or cut. The system is composed of the module level products, equipment level products, system control bus(CAN 2.0B), high speed data bus(TLK2711, 2.7Gbps) and power supply line. The main module level products include on-board computer, intelligent interface unit(PIU), transceiver, GNSS receiver, router, storage module, image processing module, data compression module, secondary power module. Module level products could be selected and form a integrated system management unit(ISMU). Power Control and Distributed Unit(PCDU) is composed by power management module, distributed module, PCU module, charge module, discharge module, etc.. These module could be selected to form an PCDU equipment, which support 100W~3000W power regulation.

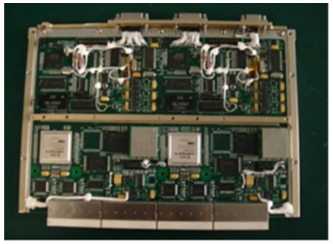
On-Board avionics system architecture

Based on the standard modular products, each satellite uses different module products combination to meet the different requirements of satellites. Each module product as a intelligent unit connect to the control bus.

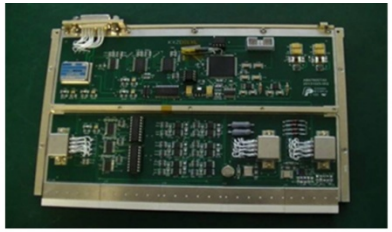
Non-intelligent sensors or actuators could be adapted by intelligent interface unit to convert to standardized bus interface. Modules with high speed data transmission requirements such as payloads, storage module, payload data processing module etc. are connected to routers, so the data flow direction is reconfigured to adapt different application.

The term intelligent refers to: support Plug-and-Play, Built-in test, acquire the operation parameters itself and check the health statement.

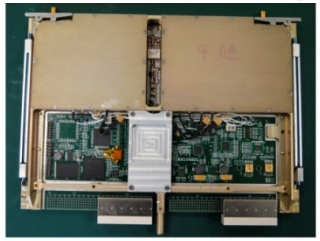
Avionics Development for microsatellites



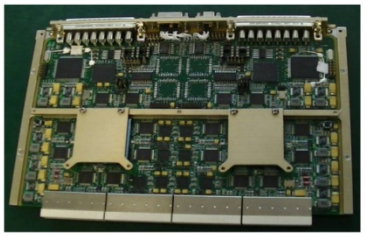
OBC



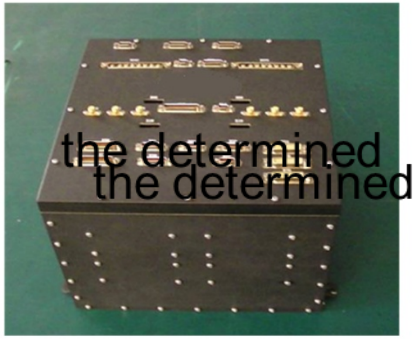
Secondary power



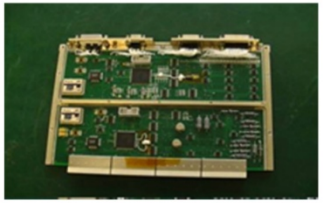
transceiver



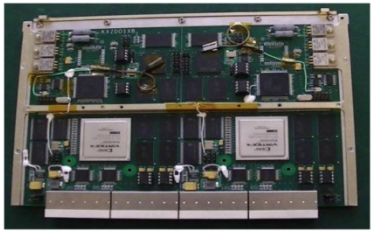
Routers



Integrated system management unit



Intelligent interface unit



Storage module

Data processing module

It integrate the function of OBC, TTC, RTU, Routers, data recorder, data processor, GNSS, etal.

Avionics Development for microsatellites

Item	Technical performance
Volume	270mm*243mm*193mm
Mass	≤8Kg
Power	28W~75W(Peak)
Reliability	≥ 0.998(6 month end)
Module	6U, combination of different modules
Bus interface	CAN2.0, TLK2711
Power Supply	24V~40V
OBC	≥ 100MIPS,4M SRAM(EDAC),RTOS
Transceiver	4096~16384bps backward, 2000bps forward
Routers	8 channel(TLK2711),10M~2000Mbps
Storage	≥768Gb(extensible)
Payload process	≥ 40GMMACs,Compression ratio:7:1 or 4:1
A/D	64 channel, 5mV precision
OC/OD output	32 OC, 200mA/Channel; 32 OD, 12W/Channel

Characters:

(1) Integrated and modular design

(2) Standardization

(3) Low cost (1/3~1/10)

(4)Plug-and-Play

(5)Built-in Test

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Lessons learned during the Development

1.Plug-and-Play (PnP) :

PnP implies that components can be “plugged” into a distributed network and they will autonomously “play” with the system to meet top level mission requirements. Here, PnP standards the OBC could recognize the terminal module(equipment) automatically, and set up the communication link.

- Dramatic reductions in component integration time with reduced hardware interface errors
- Faster debug, calibration and testing

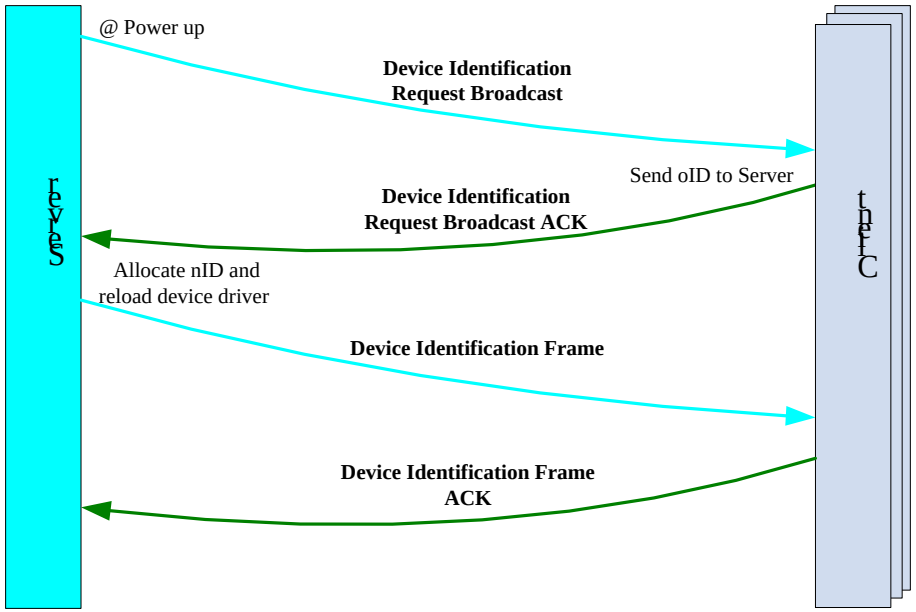
What do we need to do to implement PnP?

- Standardrized interfaces, including mechanical, power, data interfaces;
- Client-server mode
- Unique identification code
- develop driver for all the connected products, now OBC can’t recognize new type device

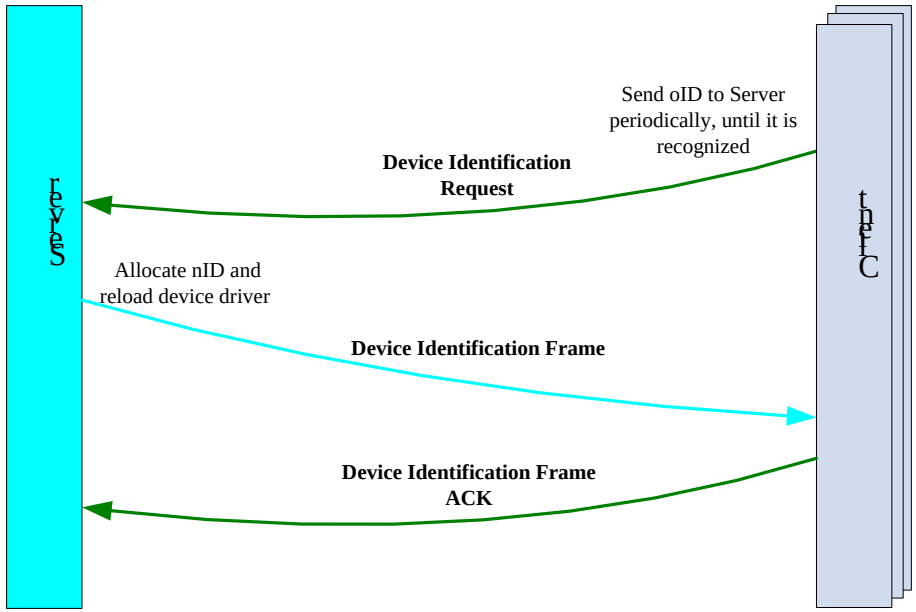
Lessons learned during the Development

Two types device discovery way as follows:

I. Server sponsored
II. Client sponsored



I. Server sponsored PnP flow



II. Client sponsored PnP flow

Lessons learned during the Development

2. Built-in-test(BIT)

Built-in-test(BIT) helps to accelerate the test during develop and assemble.

I. Module level BIT

BIT should be able to carry out real-time monitoring of the key parameters of the product, including work voltage and current. BIT also support to Generate and send the corresponding fault code.

(1) Power up BIT

- ROM memory check

The boot program and the application program is stored by three copies, the three copies are compared with each other before running.

- SRAM memory check
- Inner voltage signal check

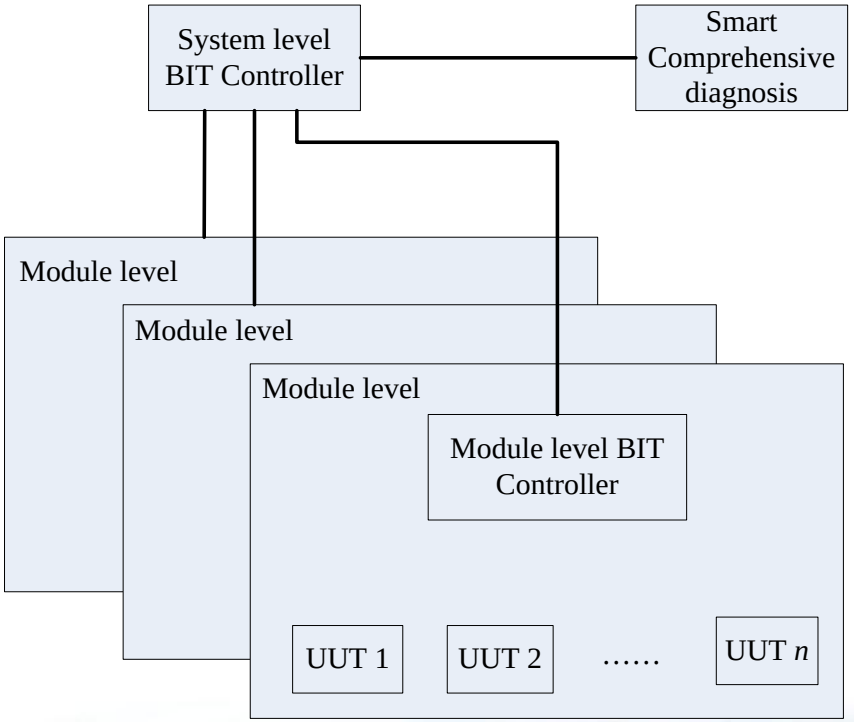
(2) Periodic BIT

- external interface monitoring, such as CAN, RS422, etal; OBC monitors the periodic communication with other nodes
- SRAM memory check
- Inner voltage signal check

Lessons learned during the Development

II. System Level BIT

System level BIT is a fast system level test when system integration or on-board test. System level BIT is mainly realized by the hierarchical design and based on the underlying module BIT design. The on-board computer act as the system level bit sponsor and organizer, and is triggered into test mode by the system level BIT instruction. In the test mode, OBC sends test instruction to other module and carry out the module level test one by one. The system BIT controller collects each module level test data and develop fault detection, localization and comprehensive diagnosis.



Lessons learned during the Development

3. COTS components selection and quality assurance

For these six-month-life remote sensing satellite, one of its character is low cost. And how to decrease the development fee of avionics?

According to our statistics to the traditional avionic equipment, the component fee make up 30% or more. The high-grade level components are very expensive, e.g. PROM UT28F256 is about 50,000 RMB, PROM HSI6664 is about 20,000 RMB. These component is not suitable for the low-cost satellites equipment. So we choose to select military/883, (automotive) industrial grade components instead to lower the component fee.

And we take some quality assurance measures to ensure the reliability of these components.

Lessons learned during the Development

the components' quality assurance level are determined by the following elements:

- component's rigorous grade: I: the component's fail makes the satellite task aborted or important performance degrade, II: the component's fail makes a slight performance degrade or no affect;
- redundancy design (single point or redundant),
- components' flight experience (yes or no),

The component's quality assurance grade is divided as 4 grade:{1,2,3,4}.

Component type		ARM9 processor	Component name	AT91RM9200
Manufacturer		ATMEL	project	XX
Attached equipment		OBC	-	-
Items			conclusion	note
Elements	Rigorous grade		I ■ II□	Flight for 2 years and
	Redundancy		Single point□ redundant■	
	Flight experience		yes■ no□	
Component's quality assurance grade			1□ 2□ 3■ 4□	

Lessons learned during the Development

According to the components' quality assurance grade determined, different quality assurance methods are adopted, as shown in the following table:

Components' quality assurance methods

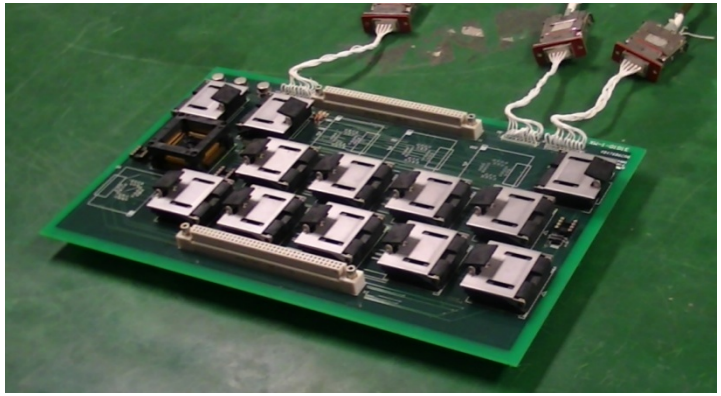
	Quality Assurance methods	Quality assurance grade				notes
		1	2	3	4	
Quality grade	MIL-PRF-38535G M, MIL-STD-883,MIL-PRF-38534 H, MIL-PRF-19500 JAN,G(+),QJB,GJB or equivalent grade	component-level screening	board-level screening	√	√	The screening test could be canceled for flight many times and works well on orbit.
	Industrial grade component	DPA, component-level screening	DPA, Component-level screening	Board-level screening	Board-level screening	

Lessons learned during the Development

Table. Component level and board level screening contents

No.	Assurance methods	Test items	MIL-STD-883G method number	requirement
1	Component-level screening	appearance check	2009	100%，10 times microscope test
2		Serial number	--	100%
3		Temperature cycling	1010	-40 ℃ ~+85 ℃ ， stay for 30minutes,10 cycles
4		appearance check	2009	100%，10 times microscope test
5		Board-level test	---	test main performance
6		Board-level burn-in test	＋65℃，96h	test main performance
7	Board-level screening	Board-level test	---	test main performance
8		Board-level burn-in test	＋65℃，96h	test main performance
Note 1：items 5,6,7 and 8 allows 5%(percent defective allowable)； Note 2：if performance abnormal during items 5,6,7,8, the invalidation analysis should be done				

Lessons learned during the Development



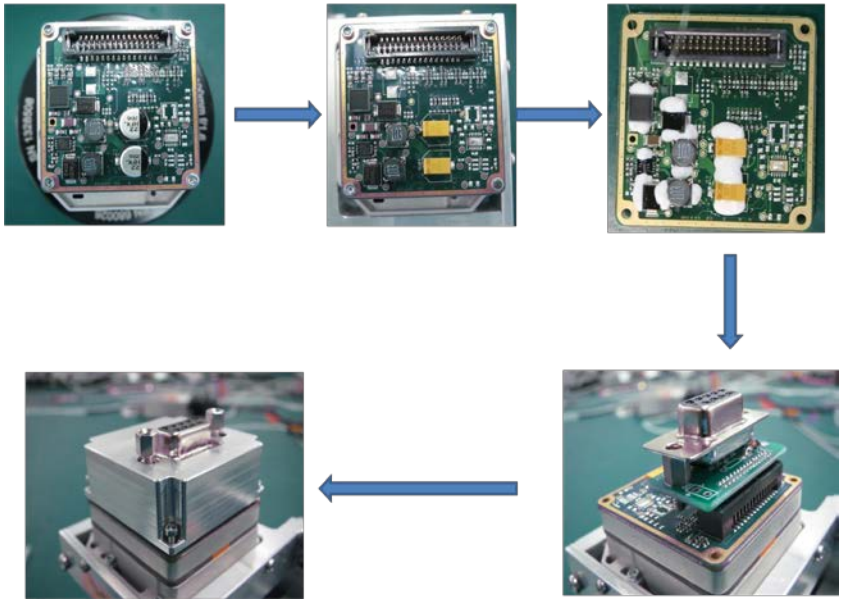
Board-level up-screening equipment

DPA program request

NO.	Items and program	GJB548B-2005 method number
1	appearance check	2009
2	X-Ray scanning	2012
3	Internal visual inspection for DPA	1010
4	Scanning electron microscope(SEM)	2018
5	Bond strength	2011
6	Die shear strength	2019

Total Ionizing Dose(TID): the TID for 1 year life LEO satellite is less than 0.1 Krad(Si)(2.54 mm Al shield protection), so the TID effect could be ignored.
Single Event Effect(SEE) is protected by the hardware and software design protect.

Lessons learned during the Development



The spatial environmental adaptability redesign for COTS

Program:

1. design analysis to recognize the key component or protection position;
2. Redesign for COTS, such as component or material replacement, thermal redesign, and resistance mechanical redesign;
3. test verification, mainly include mechanical test, thermal vacuum test and thermal cycle test. The specific test conditions are determined by the satellite's work conditions.

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Conclusion

In the development of the avionics, some other technologies are considered as follows:

- on-board data processing
- Fault detection, isolation and recovery
- inter-satellite link between formation flying satellites
- on-board task schedule

These measures are adopted in the development of avionics for the flying formation micro-satellites to enhance the ability of " quicker, better and cheaper". Here , I have shared some lessons learned in the development of avionics for micro-satellites. I think the aerospace avionics technology trend for microsatellites is:

(1)autonomy, including on-board task schedule, health management , real-time data processing and distribution.

(2)Inter-satellite link, networking and task cooperation.

(3)Produce in batches and form common production warehouse, emphasis standardization, modulation and serialization

(4)Use industrial and military level parts and COTS, new assurance requirements of EEE parts will be established.


LET'S WORK TOGETHER
CREATING A BETTER FUTURE
China Academy
of Space Technology
China Academy of Space Technology

Thanks for attention!

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